



Exploring The Bio-Stimulant In Horticulture

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Abstract: A plant bio stimulant is something you put on plants to help them use nutrients better, handle tough conditions like extreme weather, and improve the overall quality of the crop. It doesn't matter if it has nutrients or not. Plant bio stimulants can also refer to products you buy that have a mix of these helpful substances or microorganisms. Sustainable techniques for growing plants such as fruits and vegetables have been the subject of extensive research throughout the last 10 years. Extreme weather, climate change, pests, and viruses that can damage crops are all major concerns for scientists. Bio stimulants are emerging as effective instruments in contemporary horticulture, presenting sustainable avenues to elevate crop yield and fortitude. This article describes an in-depth exploration of the possibilities that bio stimulants hold within the realm of horticulture. Chitosan-derived materials showcase a range of intriguing characteristics, rendering them suitable for diverse applications, such as horticulture, where they serve as bio stimulants. Brown seaweeds are marine microalgae, as are their green and red counterparts. Their extracts are widely used in horticulture to promote crop resistance against environmental stresses such as drought, salt, high temperatures, and nutrient deficiency.

Keywords: plant bio stimulant, chitosan materials, brown seaweeds, horticulture, crop resistance

I. INTRODUCTION

Horticulture plays a crucial role to meet the increasing demands for food production and environmental sustainability. The use of bio stimulants, a group of substances that can promote plant growth and development, has garnered considerable interest in recent years due to their ability to enhance crop productivity or lower the reliance upon synthetic fertilizers and pesticides. Despite the increasing interest in bio stimulants, there is still a need for more research to fully understand their mechanisms of action and optimize their application in horticulture. In this essay, we will explore the potential of bio stimulants in horticulture and discuss their implications for sustainable horticulture.

Bio stimulants are gaining attention in horticulture as a promising tool to improve plant growth, yield, and overall crop quality (Omomowo & Babalola, 2019). These bio stimulants can include substances such as humic acid, seaweed extracts, beneficial microorganisms, and amino acids. By stimulating plant physiological processes and enhancing nutrient uptake, bio stimulants have the potential to increase crop resilience to environmental stresses, improve root development and nutrient absorption, enhance plant growth and vigour, and increase overall crop productivity (Arthur et al., 2012). They can also contribute to improving soil health and sustainability by promoting beneficial microbial activity and nutrient cycling. Additionally, bio stimulants have shown potential in reducing the reliance on chemical fertilizers and pesticides, thus promoting more sustainable and eco-friendly horticultural practices (Omomowo & Babalola, 2019). Incorporating bio stimulants into horticultural practices has the potential to revolutionize the industry by enhancing plant performance, improving soil health, and reducing environmental impacts. With the use of bio stimulants in horticulture, farmers and growers can potentially optimize fertilization and water quality, enhance nutrient quality and biological balance, suppress pests and diseases, and ultimately improve crop yield and quality. Furthermore, the use of bio stimulants can also help reduce the dependency on synthetic fertilizers and chemical inputs, leading to a more sustainable approach to horticulture.

Small amounts of organic or inorganic matter which encourage the establishment and growth of plants in a way that the plants wouldn't be able to achieve without the addition of these compounds are known as bio stimulants. They also go using the name “positive “Metabolic enhancers” or “growth regulators” (Kisvarga et al.,2022).

II. Types of Bio stimulant

2.1.Bio stimulants in horticulture- seaweed extracts

At approximately 10,000 species, macro algae, or seaweeds, contribute to the output of marine life fell by 10% world. Benthic organisms of large volume are connected to hard materials by securing. Fucoids and “kelps” are common seaweeds often seen along shorelines, easily noticeable to anyone taking a casual look . However, certain forms, like individuals in the sargassum is a type of brown seaweed found in oceans, often floating in large mats (Bhattacharyya et al.2015). Seaweed extracts, that come in liquid or soluble powder form, are the most popular seaweed-based fertilizer for gardening (Rathor et al.2015).Seaweeds have a major effect on plants and soils .They can be foliar cleaned up, employed as hydroponic solutions, or put on soil. Their polysaccharides support soil aeration, water retention, and gel formation (Patrick du Jardin, 2015).

Table 2.1. Seaweed extracts' impact on vegetable crops (Battacharyya et al.,2015)

CROP	EFFECT	SEAWEED EXTRACT
Potato	Enhanced development of seedlings upon transplantation	<i>E. maxima</i>
Eggplant	A rise in the production and development of crops Improved yields and higher rates of germination for seeds	<i>A. nodosum</i> <i>Hypnea musciformis</i> and <i>Gracilaria textorii</i>
Bean	Higher rate of germination	<i>A.nodosum</i>
Broccoli	An increase in phenolic, flavonoid, isothiocynate, and antioxidant activity increased biomass, leaf area, stem diameter, promoted early growth, and minimised albugo candida white blister	<i>A. nodosum</i> <i>A. nodosum</i> and, <i>Durvillaea potatorum</i>
Onion	Yield growth and a decrease in downy mold intensity	<i>A. nodosum</i>
Watermelon	A rise in productivity	<i>A. nodosum</i>

Cauliflower	Expanded curd diameter and yield	<i>A. nodosum</i>
Spinach	Elevated phenolic content, flavonoid content, antioxidant activity, and Fe ²⁺ chelating capacity	<i>A. nodosum</i>
Cabbage	Heightened levels of phenolics and flavonoids	<i>A. nodosum</i> commercial extracts
Pepper	Increased chlorophyll content, fruit length, diameter, and yield Higher yield of ascorbic acid and chlorophyll content	<i>A. nodosum</i> <i>A. nodosum</i> commercial extract

2.2. Fillvic and humic acids

The world's current challenges are related to creating renewable energy sources, maintaining the environment, and feeding a growing population. The main source of organic carbon at the surface of Earth is humic substances (HS), that are generated by microbial metabolism, chemical and biological changes to plant and animal garbage. They assist for the command multiple key environmental and ecological processes (Canellas et al., 2015). Humis, humic acids, and Fillvic acids are three distinct categories of heterogeneous compounds that initially fell into HS considering their solubility and molecular weights. Plant roots impact them by releasing protons and exudates; this later affects the complex dynamics of supramolecular colloids attachment and dissociation (Jardin, 2015).

2.3. Chitosan's bio stimulant actions in horticulture

Insect exoskeletons, crab shells, and fungal cell walls all naturally include the biopolymer chitin in its deacetylated form is identified as chitosan (Pichyangkura and Chadchawan, 2015). The capacity of this polycationic product to attach several parts of the cell, including the cell wall, the plasma membrane, DNA, and also to bind certain receptors related to defence gene activation, is what results in the physiological responses of chitosan oligomers in plants. As inducing agents of plant defence (Du Jardin, 2015).

2.4. The use of microalgae as bio stimulant

Strategies for farmer in the future are relevant given the demands of a growing population. Therefore, the growth of sustainable modern procedures that will both increase yields from horticulture and prevent a considerable loss of crop yields (30–70%) as a result of biotic and abiotic situations is crucial. In general, food production research is centered on yield maximization as opposed to crop quality and resource efficiency (González-Pérez et al., 2022).

2.5. Bio stimulants' function in plant development

Bio stimulants play a crucial role in enhancing plant growth and development by promoting nutrient uptake, improving stress tolerance, and stimulating beneficial microbial activity in the rhizosphere (Li et al., 2022). This increased nutrient availability and microbial activity in the rhizosphere ultimately leads to improved plant health, vigor, and yield (Ren et al., 2022). Biostimulants and Sustainable horticulture biostimulants have the potential to contribute to sustainable horticulture by reducing the need for chemical fertilizers and pesticides. Extracellular plant growth-promoting rhizobacteria and intracellular plant growth-promoting rhizobacteria are the two categories of plant growth-boosting rhizobacteria. Whereas iPGPRs are typically found inside the particular nodule formations of the root cell, ePGPRs can be found in the rhizosphere, on the rhizoplane, or in the spaces across each cell of the outermost layer of the root (Gupta et al., 2015). Enhancing the accessibility of soil nutrients, their integration, and uptake can be effectively accomplished through the use of bioactive natural substances and microbial inoculants, serving as valuable methods for agricultural improvement. Materials made from marine materials have growth-stimulating properties, so it is widely known that marine preparations can be used as biological stimulants to increase crop yields. These substances are substances that, when used in modest amounts, "support plant development in addition to fertilizers." They are also sometimes known as "the metabolic

promoters” (Khan et al.2009). When it comes to *Begonia semperflorens* Link. Et Otto, early-grown yearly decorative plants, nutrients help the plants thrive at the first low culture warmth (Boronkay et al 2022). Under both ideal and unfavorable circumstances, the phytostimulation impact of PGPR and mycorrhizal fungi may be ascribed to a number of direct and indirect processes, such as:

- (i) Better uptake and translocation of micronutrients (Fe, Zn, and Mn) as well as N and P;
- (ii) More vigorous root system apparatus (increased root biomass, surface area, and number of lateral roots), particularly in crops with a shallow root apparatus (onions, for example) or a taproot system (carrots, for example).
- (iii) A more robust antioxidant defense system;
- (iv) The regulation of plant hormones (ethylene, gibberellins, ABA, cytokinins, and auxins);
- (v) The stimulation of nutrient transporters
- (vi) The synthesis of enzymes (phosphatases) and/or the excretion of low (Rouphael and Colla ,2018).

III. Innovative Approaches to Horticulture with Bio stimulants

Implementing inoculants containing microbial species and bioactive organic compounds can be an effective way to increase the supply of nutrients in the soil and the absorption and digestion of those nutrients by plants (Rouphael and Colla ,2020).

IV. Sustainable Farming Practices with Bio stimulant Integration

In multiple study papers, a variety of bio stimulant molecules were explored. A primary goal is to meet the rising need for food production through environmentally friendly farming practices without compromising crop yield or producer income. this is because farmed soil is gradually degrading and pollution of the environment is increasing (MH Shahrajabian et al.,2021). These substances are becoming an increasingly important part of sustainable farming methods. An important concern for many has been the prevalence of threats to the environment and contaminated soil due to the careless and overuse of horticulture insecticides with a chemical base in the sector recently (Hamid et al.,2021). It has been discovered that certain algal compounds in either a direct or indirect manner promote plant development by interfering with microorganisms in the soil to promote mining for minerals or crop-microbe symbiosis, which increases the supply of nutrients(Win et al.,2018).

V. Crop Yields with Bio stimulant Applications

The rate of yield gain across various application techniques (foliar, seed, and soil) along with parameters (the rate, dosage, or interannual preparation) were studied because the use of the approach is a major efficacy predictor. A yield rise of over 17.0% was observed in both germ spray and foliar medications, which accounted for almost 85% of all experiments (Li et al., 2022).

With an emphasis on horticultural organisms, the ability to withstand abiotic conditions is a crucial characteristic since these plants often have a higher price compared to crop varieties, demand more inputs during cultivation, and are an excellent source of fiber, minerals, and carbohydrates—all the building blocks of a healthy diet. Abiotic stressors impact these products’ yield as well as quality, causing morphological, physiological, and biochemical alterations that may influence the product’s look and/or nutraceutical value and lose their marketability (R Bulgari et al., 2019).

VI. Impact of Bio stimulant on Soil Health and Plant Resilience

Rhizobacteria that support the development of crops naturally inhabit the soil when they are important for soil metabolism and the growth of plant. Other soil organisms are necessary for nearly all of the positive process that occurs in soil over time, such as the division of organic material in the soil, the creation of soil organic issues, biofixation, and biosolubilization of vitamins and minerals, as well as the decomposition of crop waste to raise crop efficiency and fertility in the soil (R Bulgari et al., 2019).

Soil health is crucial for a country's crop yield, which directly affects the food supply for its people. It's a significant issue when a nation needs external sources to fulfil its citizens' needs for food and horticultural good. The health of soil nutrients is crucial for plant well-being and forms the cornerstone of horticulture, upon which people's livelihoods rely. Soil health significantly impacts performance (Naikoo et al.,2022).

Crops grown naturally often lack essential nutrients due to either decreased nutrition soluble or reduced levels of nutrients in the soil in the root zone. In this farming system, it's crucial for growers to boost the availability of nutrients like nitrogen and phosphorus while making sure they're used efficiently. Climate studies indicate that harsh weather and unfavourable soil conditions, including salt, dryness, and extreme heat, significantly lower horticulture yields and account for around 70% of yield variations worldwide (Sani and Yong, 2021).

VII. The Future of Horticulture: Biostimulant Potential

Plant biostimulants emerge as a potential novel source of income in horticulture, supplementing agrochemicals like pesticides and fertilizers. They improve plants' ability to withstand environmental stress and enhance the productivity of horticulture products. Understanding the bioactive components of plant biostimulants and uncovering the molecular and physiological pathways they activate are crucial for both scientific research and commercial interests (Malik et al.,2020).

Enhancing crop yields can be achieved through two main approaches: boosting productivity in existing areas or expanding cultivated land. However, intensifying surface usage can deplete soil quality, while expanding agricultural land poses significant threats to ecosystems and biodiversity conservation efforts. Exploring novel techniques for stimulating and safeguarding plants with a focus on maximizing output while minimizing soil and resource usage represents a promising direction. Biostimulants, undergoing extensive research, aim to address nitrogen surplus in soil and water systems and lessen reliance on fertilizers crucial for sustaining crop production, although their overuse poses environmental pollution risk (Mattedi et al.,2023).

While the development and promotion of new bio stimulants may not presently demand a precise illustration of their mode of action, enhancing our comprehension of how various cyanobacterial strains uniquely impact plant physiology is essential to optimize the advantageous outcomes of their applications. Studies show a relationship between the bioactive substances that cyanobacteria create and how they affect the biology of plants. Yet, numerous biological, agronomic, economic, and technological challenges must be resolved before such products become widely distributed on the market (G Santini et al., 2021). Advancements in omics and related technologies, such as meta-transcriptomics, meta-proteomics, metabolomics, amplicon sequencing, and phenotyping, are enhancing our ability to analyze trace metabolites. This progress will help us better comprehend the intricate interactions among soil, microbes, roots, and shoots and, in turn, assist in evaluating plant performance and yield (Sani and W.H. Yong, 2021).

VIII. Overcoming horticulture challenges with Bio stimulant solutions

Developing sustainable and eco-conscious horticultural system is a major hurdle in meeting the demand to feed a burgeoning global population. As arable land diminishes and staple crops reach their genetic limits, the key solution lies in boosting crop yields while safeguarding our horticultural output. Improving crop quality, especially in challenging conditions, aims to boost farmers' incomes, enhance post-harvest storage, and provide consumers with more nutritious food. Plant biostimulants are usually unique mixtures made from the substance extracts from plants, organic materials, hormones resembling plants, amino acids, and humic acids, as well as the positive effects of natural biostimulants on a range of plant growth, yield, and fruit quality parameters in many crop types (Povero et al., 2016).

Plant biostimulants, which encompass natural ingredients and microbial additives, emerge as an innovative and promising class of horticultural products. They supplement agrochemicals such as artificial fertilizers, bolster tolerance to environmental stresses, and elevate the quality of agricultural and horticultural produce. The scientific community and commercial enterprises remain highly Interested in identifying the bioactive components of plant stimulants and understanding the molecular and physiological stimulation mechanisms. Utilizing small, medium, and large-scale high-throughput phenotyping emerges as the most effective approach for developing innovative biostimulants, owing to

the intricate matrices containing various groups of bioactive and signaling molecules (Rouphael and Colla, 2020).

The application of biostimulants to seeds typically encompasses three distinct methods: seed priming, seed coating, and seed dipping. Seed priming involves preparing seeds before planting by carefully hydrating them to prevent the radicle from emerging. This method improves both seed germination speed and the development of roots in plants. The application of biostimulants through foliar spraying is a widely used approach to boost crop yield across various crops, thanks to the rapid nutrient absorption by plants compared to alternative methods, leading to quicker results. The foliar spray of biostimulants improved the efficiency of water usage and the functioning of stomata in plants. Roots serve as the connection between soil and plants, supporting plant growth by facilitating nutrient uptake, responding to external stimuli, and activating defense mechanisms against stressors. Meanwhile, soil, being a limited and non-renewable resource, is fundamental to horticulture (Parmar et al., 2023).

IX. Environmental Implications of Bio stimulant Use in Horticulture

Biostimulants have gained significant attention in horticulture due to their potential to improve plant growth, enhance nutrient uptake, and promote sustainable farming practices. As the demand for organic and sustainable horticultural practices continues to rise, biostimulants offer a promising solution for farmers looking to maximize crop yields while reducing their reliance on chemical fertilizers and pesticides (Toscano et al., 2018).

The Integration of biostimulants in sustainable farming practices not only maximizes crop yields but also contributes to enhancing soil fertility and promoting the growth of beneficial microorganisms in the rhizosphere. Additionally, biostimulants play a crucial role in improving plant tolerance to abiotic stressors such as drought and temperature fluctuations, making them a valuable asset for overcoming horticultural challenges in a changing climate (Sangiorgio et al., 2020).

As we delve into the future of horticulture, it is essential to navigate the benefits of biostimulants for farmers and understand their impact on soil health and plant resilience. By leveraging the potential of biostimulants, farmers can optimize nutrient availability, enhance crop yields, and promote sustainable farming practices, ultimately paving the way for a more environmentally friendly approach to horticulture (A. Petropoulos, 2020).

While biostimulants have shown promising results in some studies, there is still ongoing debate regarding their effectiveness and long-term impact. Some critics argue that the benefits of biostimulants in horticulture may be overstated and that the long-term effects on soil health and plant resilience are not fully understood (Lisjak et al., 2019).

Furthermore, there are concerns about the environmental implications of biostimulant use in horticulture. Critics argue that widespread use of biostimulants may lead to unintended consequences such as runoff into waterways, potentially altering ecosystems and affecting aquatic life (Pascale et al., 2017).

Additionally, some researchers assert that while biostimulants may enhance nutrient uptake and improve stress tolerance in plants, these benefits may not always translate to significant improvements in crop yields. They argue that the cost-effectiveness of biostimulant applications should be carefully evaluated, especially in comparison to traditional farming practices (Franzoni et al., 2022).

As the debate over biostimulants in horticulture continues, it is essential for farmers and horticultural professionals to critically evaluate both the potential benefits and the possible drawbacks of incorporating biostimulants into their farming practices. Continued research and field trials will be crucial in determining the true impact of biostimulants on sustainable agriculture and horticultural practices (Surendra K Dara, 2021).

X. Harnessing the Power of Bio stimulants in Horticulture

Bio-fertilizers and biostimulants offer sustainable options that may alleviate the impacts of environmental and biological pressures while also improving crop quality and yield. These eco-friendly substances, such as microbes like bacteria, fungi, yeast, or microalgae, are applied in significant quantities to enhance plant growth and nutrient uptake, particularly nitrogen, phosphorus, potassium, and minerals, by colonizing the root zones. Protein hydrolysates (PHs) are a kind of plant boosters made from mixes of small protein fragments, short peptides, and amino acids obtained by partially breaking down protein sources. Protein hydrolysates (PHs) represent instances of stimulants derived from both plants and animals, able to increase

a plant's resistance to a variety of abiotic challenges and enhance a number of plant development and performance characteristics, including diameter of roots and development, blossoming, nutrient consumption efficiency, soil water retention capacity, and microbe activity (Asif et al., 2023).

Plant growth and development are significantly impacted by phytohormones. Utilizing exogenous plant hormone supplements, whether they are synthetic or derived from natural sources, has been practiced in agriculture to enhance crop production, increase yields, and minimize weed growth. Algae produce auxins, cytokinins, jasmonic acid, and other growth hormones, which can serve as biostimulants in horticultural applications. Heterocysts, specialized cells present in cyanobacteria, have the ability to convert atmospheric nitrogen to fulfil the requirements of various organisms inhabiting soil, including microorganisms, larger fauna, and flora (Choudhury et al., 2024).

Genomic methods have revealed multiple microbial genes responsible for facilitating interactions between plants and microbes. Harnessing microbial genes to promote advantageous characteristics has enormous potential for creating advanced microbial inoculants. Tillage and crop rotation are two horticultural techniques that can help create soils that reduce disease. Furthermore, by combining tiny amounts of suppressive soils with supporting soils, the disease-suppressive properties of these soils can be spread. The inconsistent establishment of the microbes, which results in ineffective delivery of desired benefits, is a significant challenge for translating findings from the lab to the field. Nonetheless, the progress in our comprehension of plant-microbiome interactions, coupled with the advanced culturing and screening methods mentioned earlier, has reignited interest in creating microbial inoculants for horticultural use (Trivedi et al., 2021).

XI. Challenges and Future Directions in Biostimulant Use in Horticulture

Challenges related to the use of biostimulants in horticulture include the lack of standardized regulations, limited scientific understanding of their modes of action, and variable efficacy across different plant species and growing conditions. Regulatory issues arise due to the diverse nature of biostimulants, which can contain a wide range of active ingredients and may not fit neatly into existing categorizations for agricultural inputs. This lack of clarity can hinder both manufacturers seeking product registration and growers trying to choose appropriate products. Furthermore, the mechanisms by which biostimulants exert their effects remain poorly understood, making it challenging to predict their performance accurately. Additionally, There are several variables that can affect how efficient biostimulants are, including the variety of soil, the weather, and plant species, necessitating more tailored research and recommendations for different horticultural systems. Despite these challenges, the growing interest in sustainable agriculture and the potential benefits of biostimulants make it an exciting area for future research in horticulture (Youssef Rouphael et al., 2020).

XII. Conclusion

Use of biostimulants in horticulture shows great potential for improving crop productivity and sustainability. By means of promoting plant development, uptake of nutrients, and resilience to stress, biostimulants offer a viable remedy for the problems encountered by modern horticulture. Nevertheless, more investigation is required to completely comprehend the modes of action of biostimulants and maximize their application in different horticultural systems. Additionally, regulatory frameworks and standards must be developed to ensure the safe and effective use of biostimulants in horticulture. Overall, the integration of biostimulants into horticultural practices has the potential to revolutionize the way we cultivate crops and address the increasing demands for food production in a sustainable manner.

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